AGE AND GROWTH OF MILKFISH *CHANOS CHANOS* LARVAE IN THE TAIWANESE COASTAL WATERS AS INDICATED BY OTOLITH GROWTH INCREMENTS

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Abstract

Age and growth of milkfish *Chanos chanos* (Forsskal) larvae collected from the surf zones of the coasts of Taiwan, April-July 1986 was studied by examination of otolith microstructure. The size (TL) of milkfish larvae at entering surf zone of the coastal waters was similar, ranged from 12.5 to 16.0 mm, averaged 14.0 mm. Age of the larvae ranged between 14 and 29 days old, averaged 20-days old. Mean daily age of the larvae in the eastern coast (16-20 days old) was smaller than that in the southwestern coast (20-24 days old). The daily growth rate of the otoliths of milkfish larvae dropped down suddenly to a low level from approximately 10-13 days after hatching. Somatic and otolith growths were uncoupling for the milkfish larvae from the southwestern coast; the otolith diameter increased while fish length remained constant.

Introduction

Milkfish *Chanos chanos* (Forsskal), a popular and important food fish in Indonesia, Taiwan and the Philippines, is widely distributed in the tropical and subtropical areas of the Pacific and the Indian Oceans (Schuster 1960).

Milkfish has been cultured over 300 years in Taiwan. For cultivation, milkfish fry are collected along the coasts during the spawning season in large numbers. Due to seasonal environmental conditions and natural fluctuation in yearly recruitment, the supply of the fry is unstable. Although induced spawnings of milkfish had been attempted (Liao et al. 1979; Lin 1984), very limited quantities of fry were produced and the supply of milkfish fry is still largely dependent on naturally recruited stock. Much research on the behaviour of milkfish larvae in relation to environmental conditions has been conducted to improve the catch efficiency of wild fry (Buri and Kawamura 1983; Buri et al. 1981; Kawamura et al. 1980; Kumagai 1984; Kumagai and Bagarinao 1979, 1980; Liao et al. 1977). However, the growth history of milkfish larvae still remains obscure.

Since the daily formation of growth increments in fish otolith was reported by Pannella (1971), aging larval and juvenile fish by counting daily increments has become a widely used technique in studying the early life history of the fish (Brothers 1981; Campana and Neilson 1985). Thus, the research on the timing of spawning, growth rate and of life history transitions have often involved examination of otolith microstructure. Growth increments in otoliths of milkfish larvae were obviously observed (Kawamura and Washiyama 1984) and validated to be deposited in a daily schedule (Tzeng and Yu 1988; 1989). Thus, it is possible to study the growth history of wild-captured milkfish larvae by aging technique.

This paper sought to determine the age of milkfish larvae entering the coastal waters of Taiwan and to analyze the growth history of the larvae by examining the otolith microstructure.

Materials and Methods

The samples of milkfish larvae were collected with a skimming net from the surf zones of Tour-Cherng (TC) and Cherng-Gong (CG) in the eastern coast of Taiwan, and Dong-Gaang (DG), Chyi-Jin (CJ), Horng-Mau-Gaang (HMG) and Mi-Two (MT) in the southwestern coast of Taiwan from April through July 1986 (Fig. 1). The samples collected almost covered the major fishing grounds and the main fishing season of the milkfish fry in Taiwan (Tung 1969; Kumagai 1984).

A total of 500 milkfish larvae were collected. The larvae were immediately preserved in absolute ethyl alcohol after sampling. Total lengths of the larvae were measured to the nearest 0.1 mm under profile projector at magnification 10X after 1-week fixation. Then, both sagittal otoliths from each of the 150 larvae were removed and mounted with Permount on a microscope slide with proximal surface down. The discrimination of daily growth increments in otoliths of milkfish larvae was described in the previous study (Tzeng and Yu 1988). Otolith radius measurements and daily growth increment counts were made with a Video-Microscope-IBM/PC image analysis system (VID-512) at magnification 400X-1000X. Daily ages of the larvae were estimated using the equation:

$$N = D-1$$

Where N is the number of growth increments in the otolith, and D is the age in days after hatching for the larvae.

Homogeneity test of the compositions of fish size and daily growth increment of milkfish larvae from different sampling areas were made using Scheffe's multiple comparison method (Sokal and Rohlf 1981). The total length / age and otolith radius / age relationships were fitted with linear regressions (Snedecor and Cochran 1969).

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Results

1. Size compositions of fish

Frequency distributions of the total length of milkfish larvae collected from various dates and localities in the coasts of eastern and southwestern Taiwan are shown in Fig 2. Total length of the larvae ranged from 12.5 to 16.0 mm, averaged approximately 14.0 mm. The size compositions of most milkfish larvae among different sampling localities and months were not significant ($P>0.05$), except those from CG on 28 April being significant difference with those from CJ on 8 May and HMG on 11 May ($P<0.01$). This indicated that the size of most milkfish larvae in the surf zones were similar. The short-term growth of milkfish larvae in the surf zones was discernable, because the mean and mode of total length of the larvae apparently shifted with the sampling time for the larvae collected from TC, CG and CJ.

2. Otolith increment

When viewed under the microscope with transmitted light, the otoliths of milkfish larvae revealed a thick amorphous primordium and a bipartite structure of dark and light bands which corresponded to the heavily calcified incremental and organic-rich discontinuous zones (Fig. 3). An incremental zone plus a discontinuity zone is generally assumed to represent one day, and the relationship between the number of growth increment (N) and the daily age (D) was $N=D-1$ (Tzeng and Yu 1988). The growth increment of the otolith of Fig. 3A was counted to be 17 and the otolith of Fig. 3B was 21. Accordingly, these two larvae were estimated to be 18- and 22-days old, respectively. The increment width of the otolith was distinctly smaller and narrower in the 22-days old milkfish larva (Fig. 3B) than in the 17-days old larva (Fig. 3A), although total length of these two larvae was the same, 13.9 mm. This indicated that the growth rate was lower in the 22-days old milkfish larva than in the 17-days old larva.

3. Daily age of milkfish larvae in the surf zones

The daily age of milkfish larvae in the surf zones ranged between 14- and 29-days old, with an average of approximately 20-days old (Table 1). The daily age of the larvae varied with locality and sampling date. The mean daily age of the larvae from the southwestern coast (19.5-24.4-days old) was significantly older than those from the eastern coast (15.5-20.0-days old) ($P<0.01$). On the other hand, there was a tendency that the daily age of milkfish larvae was older in the later month than in the early month, e.g., the mean daily age of the larvae collected from Tour-Cherng (TC) was 15.5-days old on 4 May and 19.8-days old on 1 June. It was also true for those from Cherng-Gong (CG) and Chyi-Jin (CJ).

4. Transition of growth rate of otolith

The daily changes of growth rate of the otoliths of milkfish larvae collected from Tour-Cherng (TC) on 4 May and Chyi-Jin (CJ) on 8 May indicated that increment width of the otoliths apparently became narrow from approximately the 9th-12th daily growth increment (10-13 days after hatching), the mean values of increment width of the otoliths decreased from 5.1-6.3 μm/day to 4.5 μm/day below in TC area and from 3.7-5.0 μm/day to 2.9 μm/day below in CJ area (Fig. 4). This phenomenon was also found in the other area (Kawamura and Washiyama 1984). These may suggest that milkfish larvae had undergone a transition of growth history before entering the surf zones.

5. Somatic and otolith growths

The growths of milkfish larvae in the surf zones were expressed by linear regressions of total length and otolith radius on daily age. Regression of total length (TL) on daily age (D), $TL=12.77+0.06D$ ($15<D<24$, $n=78$, $r=0.27$), was significant for the milkfish larvae collected from the surf zones of the eastern coast ($0.01<P<0.05$) and not significant for those from the southwestern coast of Taiwan ($P>0.05$). However, regressions of otolith radius (OR, μm) on daily age (D) for the milkfish larvae both from eastern coast ($OR=57.6+1.6D$; $14<D<26$, $n=78$, $r=0.53$) and southwestern coast ($OR=51.1+2.0D$; $14<D<29$, $n=72$, $r=0.61$) were highly significant ($P<0.01$). The somatic and otolith growths were uncoupling for the larvae in the southwestern coast.

Discussion

The growth rate of the otoliths of milkfish larvae dropped to a low level from approximately 10 to 13 days old (Fig. 4). Since smaller larvae were not available in this study, we could not compare the concurrent change of somatic growth of the larvae with the transition of the growth of otoliths to interpret the biological significance of the sudden drop of the growth rate of the otoliths of milkfish larvae during the larval life period. However, Kumagai (1984) indicated that milkfish postlarvae smaller than 9-10 mm TL were distributed in midwaters, beyond this size the larvae began to rise to the surface and migrated toward the shore. Judging from the daily age and size of milkfish larvae appearing in the surf zone (Table 1, Fig. 2), the sudden drop of the growth rate of the otoliths of 10-13-days old milkfish larvae might coincide with the transition of the ecobehaviour of the larvae mentioned above.

The daily age of milkfish larvae in the surf zones of Taiwanese coastal waters averaged approximately 20-days old (Table

1), which was very similar to the speculation from the reared larvae by Liao et al. (1979). However, the daily ages of milkfish larvae from the southwestern coast was generally greater than those from the eastern coast of Taiwan. The spawning grounds of milkfish was presumed to be located off eastern Taiwan (Liao 1971; Tung 1969). Accordingly, milkfish larvae which drifted from the spawning ground to the southwestern coast needed more time than that drifting to the eastern coast. On the other hand, the growth rate might also affect the age of the larvae arriving at surf zones, e.g., the growth rate of the otoliths of milkfish larvae was smaller in the southwestern coast (Fig. 4B) than in the eastern coast (Fig. 4A). The slow-growing milkfish larvae might prolong their larval life and delay metamorphosis to juvenile stage (Victor 1986). Milkfish larvae disappeared from the surf zone in the middle of their transition from larvae to juvenile (Taki et al. 1987). Probably due to these reasons the daily age of milkfish larvae was greater in the southwestern coast than in the eastern coast.

The somatic and otolith growth rates were uncoupling for the milkfish larvae from the southwestern coasts of Taiwan. This uncoupling phenomenon was frequently found in other species (Brother, 1981; Rice et al. 1985; Wilson and Larkin 1982). The probable mechanism for this might be due to the fact that the growth of otoliths was synchronized with photoperiod, and the otoliths continued growing in size even during starvation and negative growth (Mosegaard et al. 1988; Tanaka et al. 1981).

In addition, milkfish larvae stayed in the surf zone quite short as indicated by their daily age (Table 1). Thus, total length (TL) of milkfish larvae in the surf zone was similar; the larvae appeared in the surf zone approximately from 12.0-13.0 mm TL and disappeared from the surf zone when the larvae larger than 15.0-16.0 mm TL (Fig. 2), which might be due to the transition of ecobehaviour of the larvae (Kumagai 1984). Probably due to this fact, the growth of milkfish larvae in the surf zone was not obvious.

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Table 1. Daily age of milkfish larvae collected in the eastern (TC and CG) and southwestern (DG, HMG, CJ and MT) coasts of Taiwan, April-July 1986.

Location	Sampling date	Age in days			
		n	mean	S.D.	range
TC	May 4	15	15.5	1.13	14-18
	Jun 1	19	19.8	1.90	18-25
CG	Apr 28	12	17.9	1.83	16-21
	May 12	16	19.1	2.32	15-24
	Jul 4	16	20.0	2.10	19-26
DG	Apr 26	17	19.5	2.42	14-23
HMG	May 11	14	20.4	1.91	18-24
CJ	Apr 20	17	22.8	2.20	20-24
	May 8	11	24.4	3.07	21-29
MT	May 23	13	23.0	2.93	18-27
Total		150	20.4	2.18	14-29

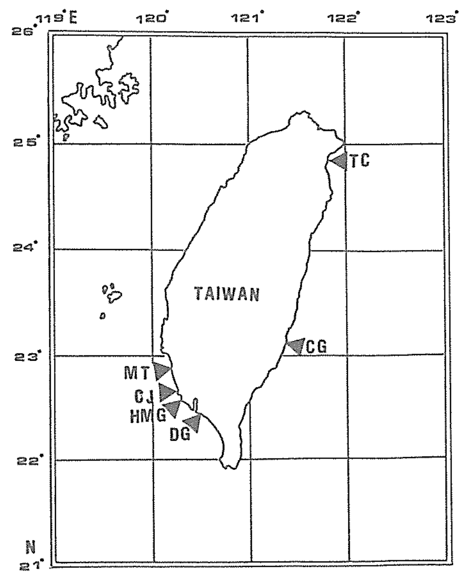

Fig. 1. Map showing sampling site (▲) of milkfish larvae in the coast of Taiwan.

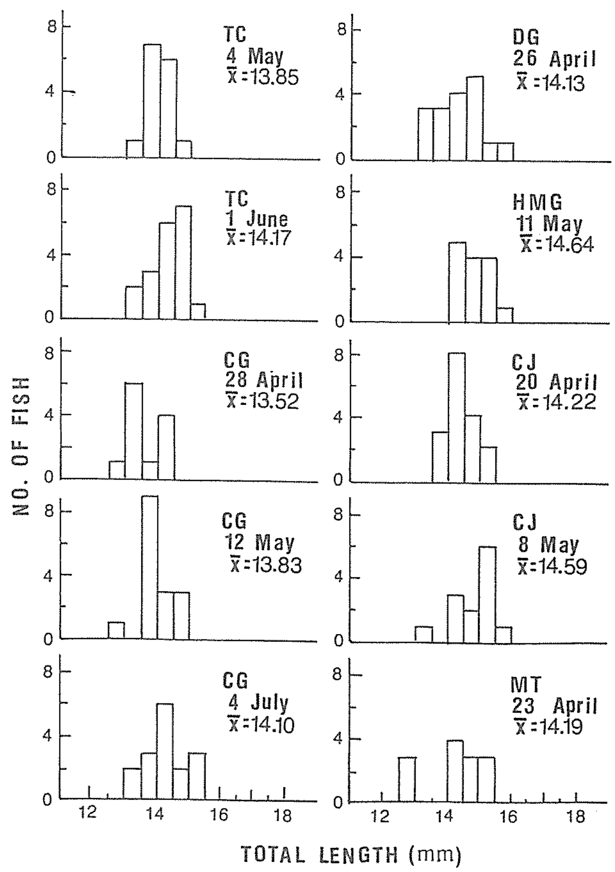

Fig. 2. Frequency distribution of total length of milkfish larvae. The sampling site (TC, CG, DG, HMG, CJ and MT) refer to Fig. 1.

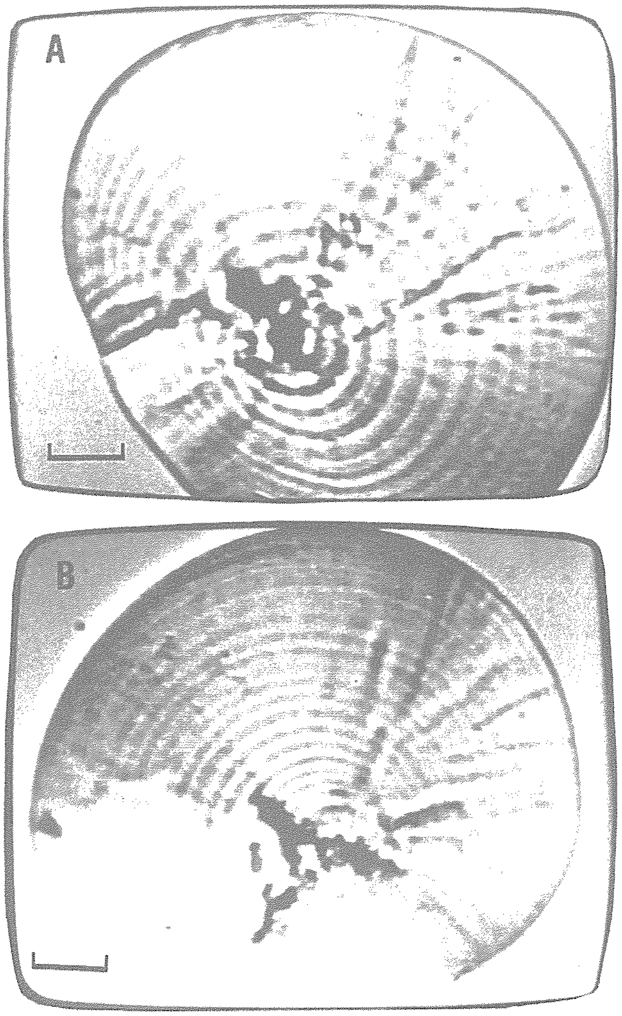

Fig. 3. Image-processed photographs showing the growth increments in sagittal otoliths from two same size milkfish larvae (13.9 mm TL) collected in the surf zone of Tour-Cherng on 4 May 1986. A: The otolith with 17 daily growth increments (DGI), 88.5 µm in maximum otolith radius (OR); B: DGI, 21; OR, 79.8 µm. Scale bar = 20 µm.

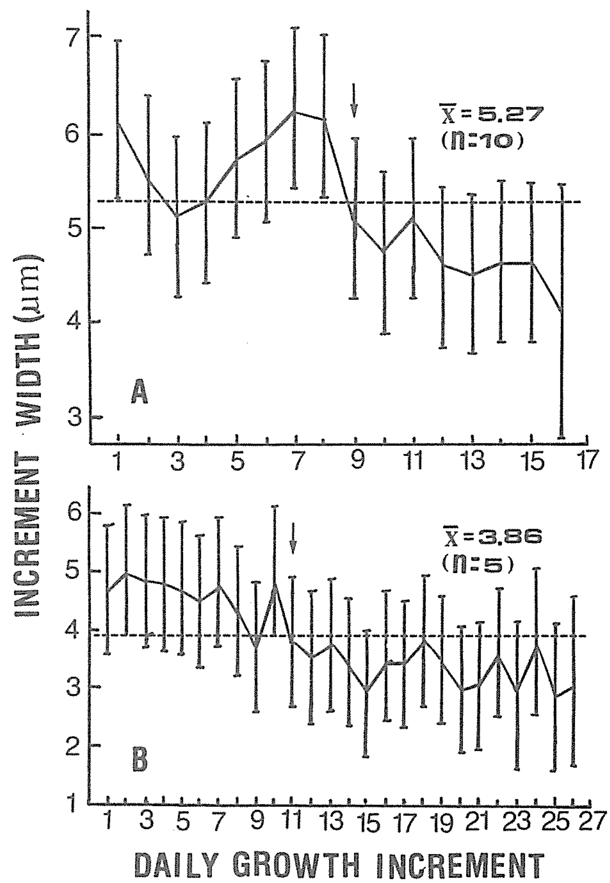

Fig. 4. Mean daily increment width along maximum radius of the sagittal otolith of the larvae collected from A: Tour-Cherng on 4 May 1986; B: Chyi-Jin on 8 May 1986. Vertical lines = 95% confidence intervals. $\overline{X}$ = overall average of increment widths, n = sample size. Arrows indicate the timing from where the transition of otolith growth occurred.